APPENDIX B
TO LESSON PLAN 11

PRESENTATION OF EQUIPMENT

STUDENT HANDOUT

B-1. SCOPE.

This handout includes a basic description and principle of operation of the following:

a. Simulation with laser light
b. The TWGSS firing system
c. The TWGSS target system

B-2. SIMULATION WITH LASER LIGHT.

a. TWGSS uses a low-power laser which is classified as eye-safe. It differs from the laser used in fire control equipment rangefinders, which has far greater power and requires adherence to strict safety regulations. The laser light used in TWGSS is compatible with the laser light used by MILES. This means that the lasers transmit light at the same frequency.

b. Laser light travels in a straight line at a very high velocity, the highest velocity known. Therefore, it cannot be used directly to simulate a curved projectile trajectory. Compared with the speed of laser light, the projectile moves at a very low speed. A laser pulse reaches a target 1000 m away in about 3.3 microseconds ($3.3x10^{-6}$). It takes 200,000 times longer (0.7 s) for a projectile to reach the same target if the velocity of the projectile is 1450 m/s. See Figure 1.

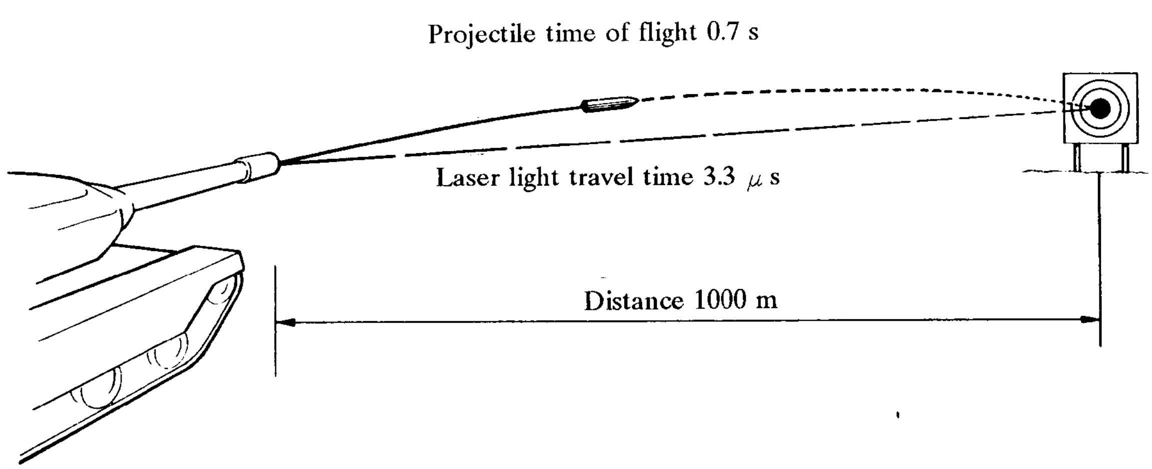

Figure 1.

B-2. SIMULATION WITH LASER LIGHT (Con't).

c. Targets used during precision gunnery training with TWGSS must be equipped with retro reflector units which reflect the light back to the firing system. The retro reflectors are used to determine where the simulated round hits in relation to the target.

B-3. TWGSS FIRING SYSTEM.

a. The firing system goes through a cycle each time the system simulates firing. The only exception is the ammunition assignment which is performed when the TDRS memory card is downloaded at TWGSS power up. Loading, sighting, and firing are manual steps, while other parts of the cycle are carried out automatically by the firing system.

b. All steps in the firing system simulation cycle are illustrated in Figure 2 and described as follows:

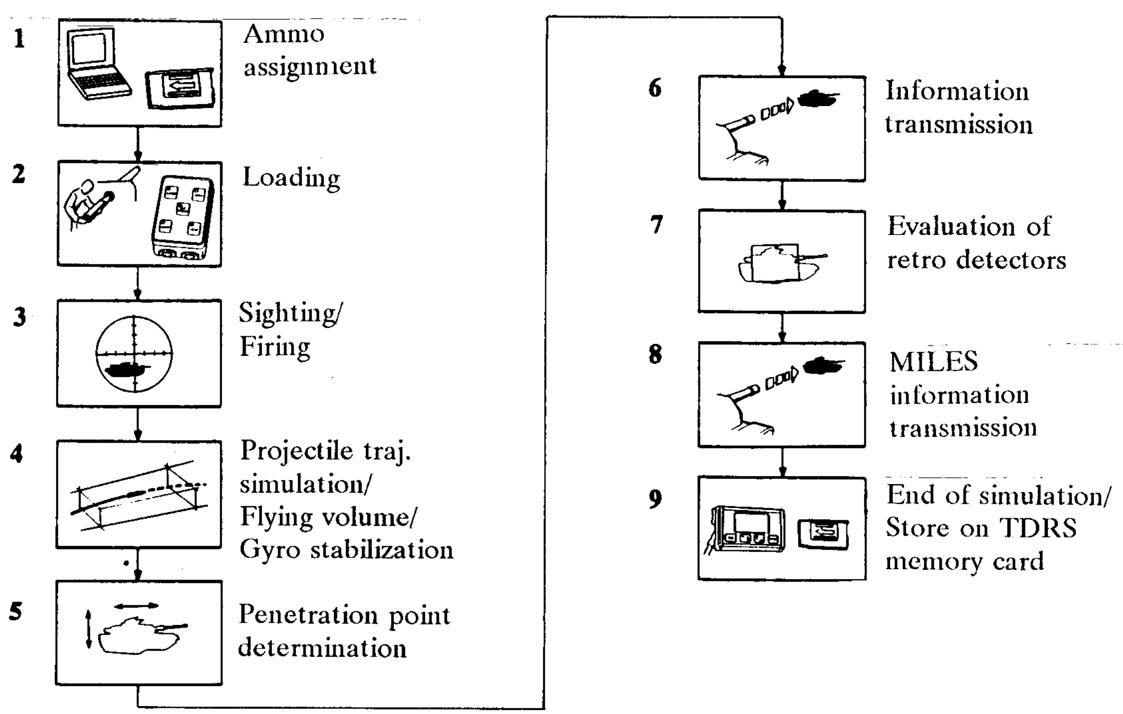

Figure 2.

B-3. TWGSS FIRING SYSTEM (Con’t).

(1) **Ammunition assignment.**

Note. Refer to detail 1 of Figure 2.

(a) Before the training exercise starts, the vehicle is assigned ammunition by the instructor who programs the TDRS memory card using the TDRS computer unit. When TWGSS is powered up, the data from the TDRS memory card is downloaded into TWGSS.

(b) The data contains information on how much and which type of ammunition the system will carry during the exercise. The ammunition assignment is stored in a memory; each time the firing system simulates firing, the remaining ammunition is decreased.

(c) If ammunition runs out during the exercise, new ammunition must be assigned by the instructor using the TDRS computer unit or a control gun (CGUN).

(2) **Loading.**

Note. Refer to detail 2 of Figure 2.

(a) In tanks equipped with automatic loading, simulated loading and weapon selection are carried out, using the normal procedure. In manually loaded tanks, simulated loading is done with a loader's panel where each ammunition can be selected for loading.

(b) The amount of time needed to load the gun with the actual projectile is simulated by the firing system. Therefore, the time between two simulated firings cannot be made shorter than during actual live fire.

(c) The firing system also has the capability to simulate ammunition stored in the hull of the tank. TWGSS simulates the time it takes to move the ammunition from the hull/semi-ready racks to the turret ready racks. The upload time is adjustable.

(3) **Sighting and firing.**

Note. Refer to detail 3 of Figure 2.

(a) The tank's normal fire control system (FCS) and sights are used during engagements with TWGSS. Firing of a simulated round is carried out in the same way as during live fire.

(b) TWGSS is programmed with combat ammunition based upon firing table data. This means that specific ammunition temperature, air temperature, etc. must be programmed into the tank for correct firing results.

B-3. TWGSS FIRING SYSTEM (Con't).

(c) The correct lead angle and superelevation of gun must always be applied for a successful engagement.

(4) **Projectile trajectory simulation.**

Note. Refer to detail 4 of Figure 2.

(a) When a round is fired with TWGSS, simulation of the projectile begins in the transceiver unit. The purpose of this simulation is to determine the projectile's position in space continuously throughout the time of flight. This is done through ballistic calculations based upon firing table data.

(b) Simulation starts in the direction the gun barrel is pointing at the instant a live projectile would have left the muzzle of the gun. This direction is called the reference direction (see Figure 3).

(c) The reference direction is used as reference to calculate the position of the projectile during simulation. This direction is gyro stabilized which means that the gun barrel can move without affecting the simulated projectile's position during time of flight.

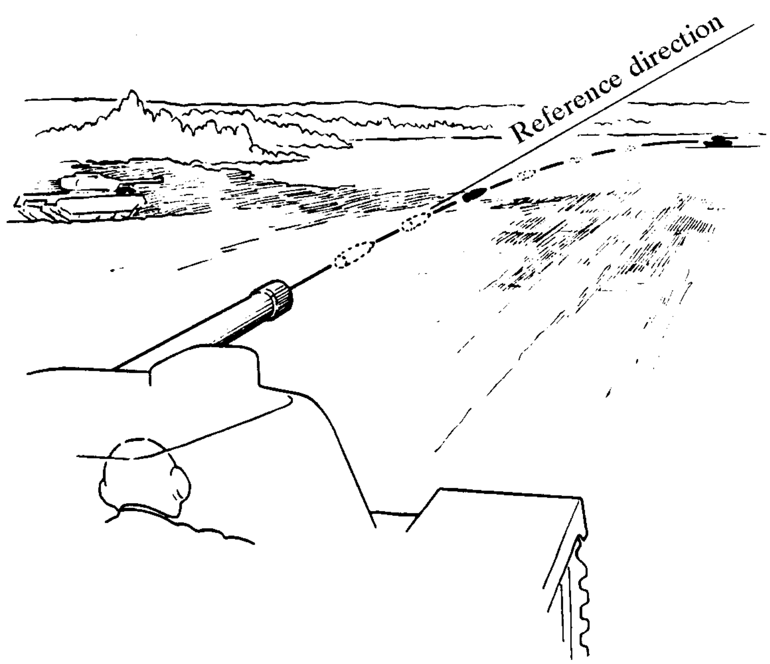

Figure 3.

B-3. TWGSS FIRING SYSTEM (Con't).

(5) Flying volume.

Note. Refer to detail 4 of Figure 2.

(a) Laser light is sent out from the transceiver unit in long, narrow, pulsed beams called lobes. By combining the transmission and reception of laser light within the transceiver unit, the firing system creates something called the flying volume (see Figure 4).

(b) This flying volume follows the same trajectory the live fired projectile would have taken. It follows the projectile continuously, and the simulated projectile is always in the center of the volume. The flying volume has the same velocity and trajectory as the projectile and is continuously scanned by pulsed laser lobes from the transceiver unit.

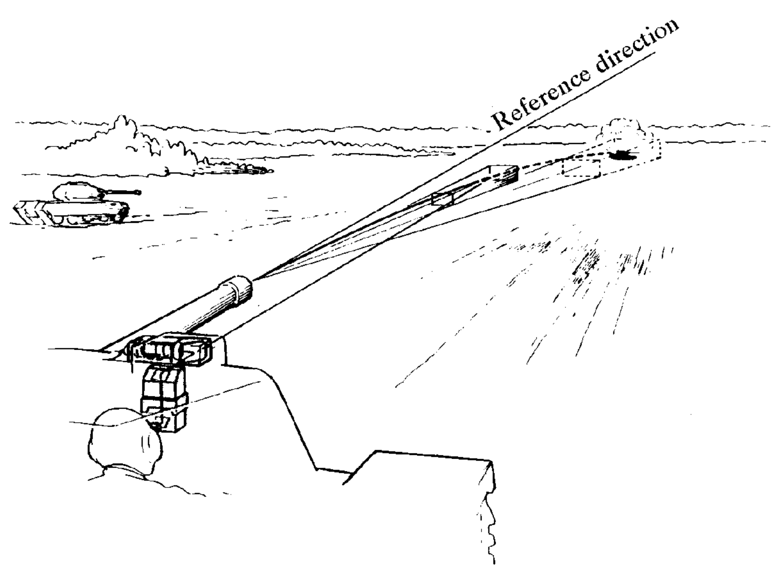

Figure 4.

(c) Assume the gunner lays on a moving target and has applied the correct superelevation and lead angle. Since the flying volume follows the same trajectory as a live projectile and the flying volume velocity corresponds to that of the live projectile, it will cover the target at that instant when the projectile either strikes or passes the target. If a retro detector unit facing the firing vehicle has been mounted on the target, the laser light will be reflected back to the transceiver unit, and the position of the target can be determined.

B-3. TWGSS FIRING SYSTEM (Con't).

(d) The dimension of the flying volume and its position is determined by the projectile simulated. The faster the round, the longer the flying volume.

(e) The position of the flying volume is updated approximately 15 times per second and with the trajectory of the simulated ammunition type.

(f) The position of the simulated projectile within the flying volume is updated approximately 200 times per second, through the ballistic calculation performed by the transceiver unit.

(6) **Sweep.**

<u>Note</u>. Refer to detail 4 of Figure 2.

The transceiver unit scans the laser lobes vertically and horizontally. This scan provides a horizontal sweep, as shown in Figure 5, which is used to search for targets within the flying volume. The vertical scan is used to lower the projectile during its trajectory simulation.

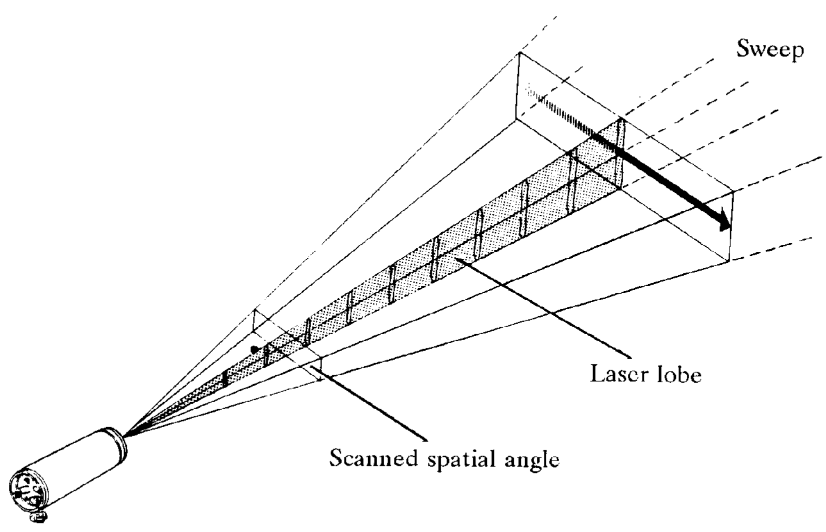

Figure 5.

(7) **Projectile velocity.**

<u>Note</u>. Refer to detail 4 of Figure 2.

The transceiver unit receives all reflections, but only those reflections which arrive from retro detector units located within the flying volume are processed. Figure 6 shows a target which is illuminated by laser light, but the flying volume has not yet reached the target. Therefore, its reflections are not yet processed by the transceiver unit.

B-3. TWGSS FIRING SYSTEM (Con't).

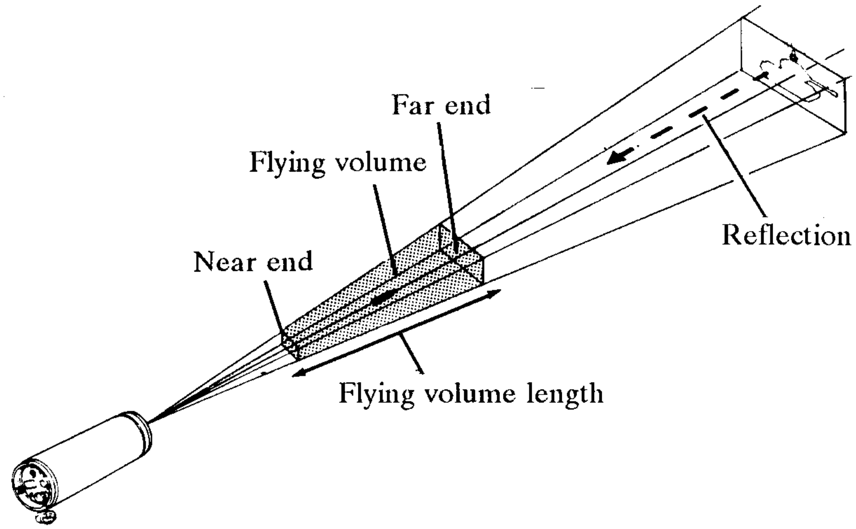

Figure 6.

(8) **Curved projectile trajectory.**

<u>Note</u>. Refer to detail 4 of Figure 2.

(a) Since the actual projectile trajectory is curved, the laser lobes must be lowered as the simulated projectile moves away from the muzzle so the flying volume will always be located around the simulated projectile.

(b) Figure 7, which is highly exaggerated, shows three different projectile positions during simulation. At the first position, the projectile has deviated very little from the reference direction. At the second position, the projectile has dropped and the flying volume (scanned area) must be lowered relative to the reference direction.

B-3. TWGSS FIRING SYSTEM (Con't).

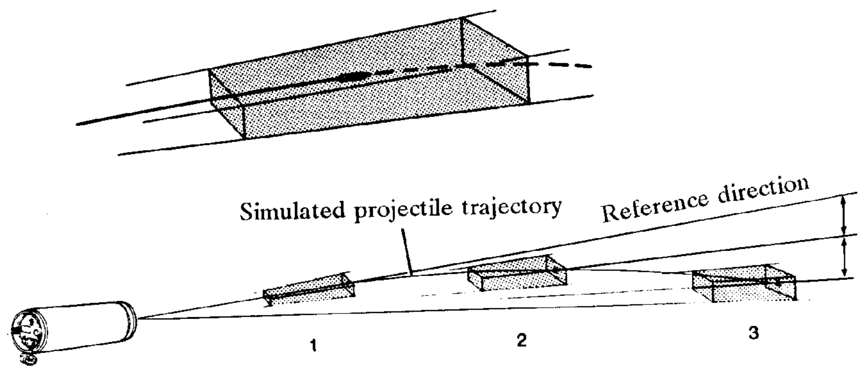

Figure 7.

(9) **Gyro stabilization.**

Note. Refer to detail 4 of Figure 2.

(a) Gyros in the transceiver unit sense gun barrel movement. During the projectile's time of flight, the transceiver unit calculates the extent to which the gun barrel has moved away from the reference direction.

(b) A gyro signal is generated which is used to:

1. adjust the position of the sweep in order to stabilize the simulated projectile in the air;
2. adjust the position of the tracer, burst, obscuration simulator (TBOS) simulation of the tracer in the tank's sight; and,
3. calculate impact on the target.

(c) If, for example, the gun barrel is moved to the left after firing, the sweep also moves to the left since the transceiver unit is mounted in the gun barrel. The gyros in the transceiver unit sense this movement, and a gyro signal is generated which moves the sweep to the right (see Figure 8). This means that the flying volume's sweep is kept in the same position as at the instant of firing (before the gun barrel was moved). As shown in Figure 8, the total deflection area is large relative to the sweep.

B-3. TWGSS FIRING SYSTEM (Con't).

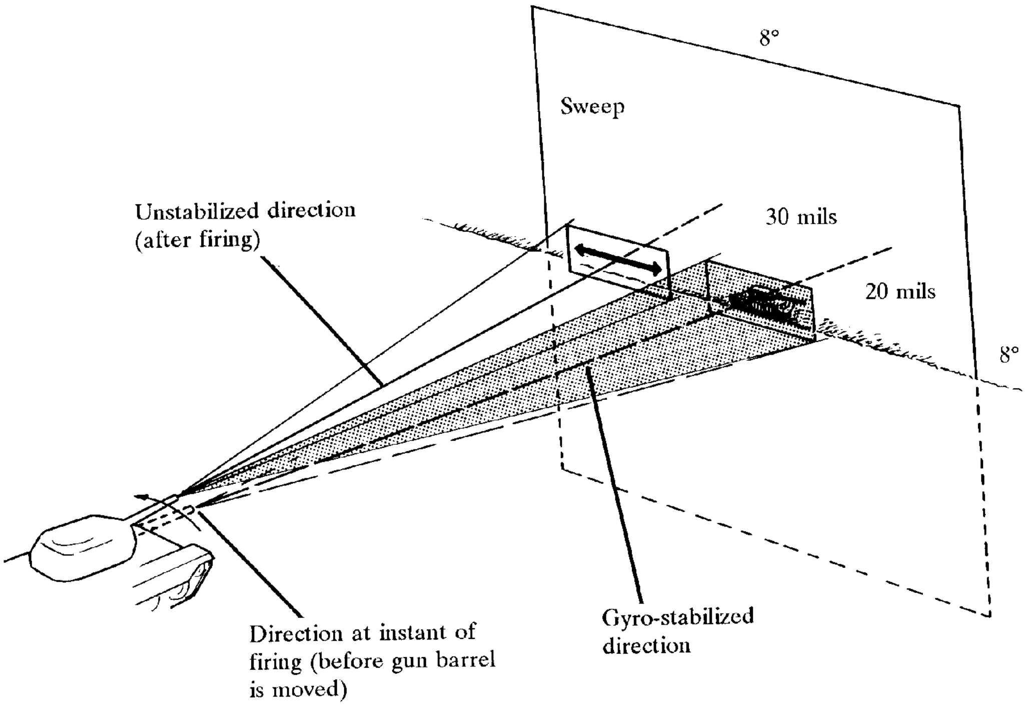

Figure 8.

(10) **TBOS**

Note. Refer to detail 4 of Figure 2.

(a) The TBOS effects of a projectile are simulated into the gunner's and commander's sights. The TBOS units are installed in front of the sights. These units contain a semi-transparent mirror on which the TBOS effects are projected (see Figure 9). The gunner and commander see the surrounding terrain through the mirror as well as the projected TBOS effects. This makes for realistic TBOS effects.

(b) For some vehicles, the TBOS effects are injected electronically into the sight of the vehicle. For these vehicles, there is no need to install the TBOS unit in front of the sight.

(c) TBOS effects are ammunition dependent. The following TBOS effects are simulated:

1. Obscuration
2. Tracer
3. Burst on target
4. Burst on ground

(d) The position of the tracer in the sight is controlled by the projectile trajectory simulation and gyro stabilization. This enables the tracer simulation to have the same trajectory as the simulated projectile. The size of the tracer is reduced as the distance between the projectile and the muzzle increase.

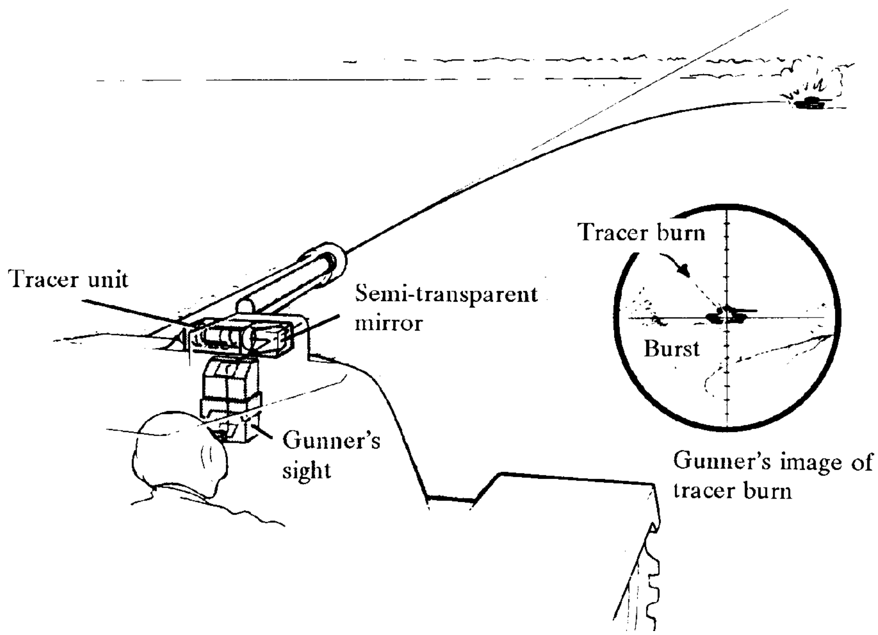

Figure 9.

(e) If the simulated projectile strikes the target or the ground, there will be a burst simulating the impact. The burst on target effect is larger than a burst on ground effect. Different types of ammunition have different sizes of burst effect depending of the capability of that ammunition.

(11) **Hit point determination.**

Note. Refer to detail 5 of Figure 2.

(a) Hit point determination is carried out when the flying volume covers the target. Figure 10 shows the principles used to determine the point of impact for a laser lobe.

B-3. TWGSS FIRING SYSTEM (Con't).

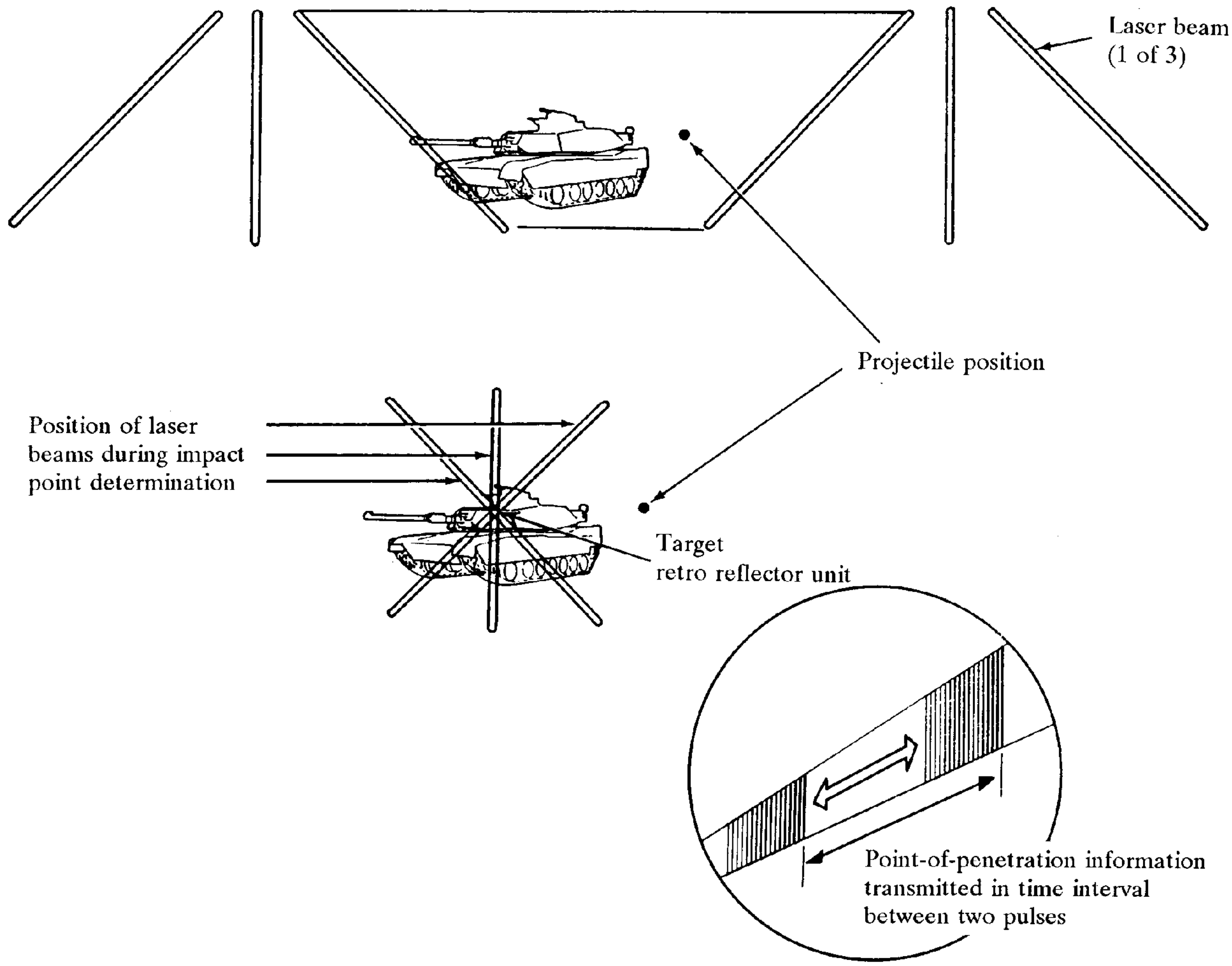

Figure 10.

(b) The transceiver unit, which scans the lobes, provides continuous information about the current position of the lobes. When a reflection is detected by the transceiver unit, the angular position of the lobe is determined. The reference used for this reading is the direction of the simulated projectile at the instant of reflection.

(c) The angle that is read is a measurement of the lateral position of the point at which the simulated projectile hit the retro detector unit on the target. By calculating the range in meters to the retro detector unit (target range), the angle can be converted to a hit point (expressed in meters) in relation to the detector.

(12) **Information transmission.**

B-3. TWGSS FIRING SYSTEM (Con't).

Note. Refer to detail 6 of Figure 2.

(a) Hit point information is transmitted to the target vehicle so that the target system, mounted on target vehicle, can calculate where the hit occurred and the extent of the damage to the vehicle (probability of kill).

(b) Hit point information is transmitted in coded form during the intervals between laser lobe pulses (see Figure 10). The laser lobes transmit not only hit point information, but also vehicle identity and the type of ammunition fired.

(13) **Evaluation of reflections and laser lobe sweeps.**

Note. Refer to detail 7 of Figure 2.

(a) Reflections are evaluated on two occasions:

1. After one sweep with the lobes
2. After two or three sweeps

(b) When a lobe sweeps past a retro detector unit, 6-7 pulses are reflected. The average value of these pulses is calculated and stored in the transceiver unit (see Figure 11). During a sweep, a number of reflections from each lobe and each retro detector are averaged and stored. Evaluation is carried out after three sweeps. If all three sweeps contain reflections from the same target, the average value is calculated. The point of impact is checked against a target template (see Figure 12).

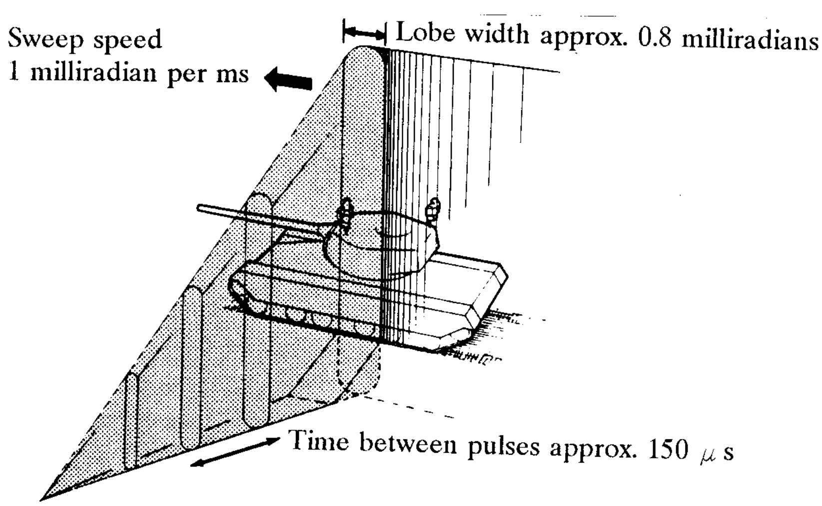

Figure 11.

B-3. TWGSS FIRING SYSTEM (Con't).

(c) If the point of impact lies within the area covered by the target template, the round is considered as being aimed at this target (see Figure 12). As a result, the tracer becomes brighter to simulate the projectile's burst, after which the burst is extinguished and the simulation is stopped. After simulation, the firing result is presented on the control panel and stored on the TDRS memory card for AAR (see detail 9 of Figure 2).

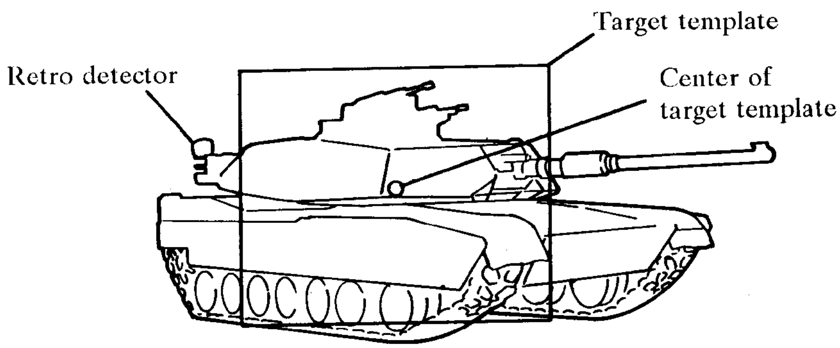

Figure 12.

(d) If the point of input lies outside the template, the tracer and simulation continue until another target is hit or until the maximum range of the ammunition has been reached. The maximum range corresponds to the maximum range for the ammunition fired, that was programmed on the TDRS memory card and downloaded into TWGSS at power up.

(14) **Hit templates used.**

Note Refer to detail 7 of Figure 2.

(a) Panel gunnery.

1. During panel gunnery, the template used to evaluate hit or miss depends on which ammunition type the gunner has fired. For ammunition intended to kill tanks, a T80 frontal target is assumed. For ammunition intended to kill APCs, a BMP front is assumed. For ammunition used to engage personnel, a kneeling soldier is assumed.
2. TWGSS is designed so that the panel target has a retro reflector unit installed in the center of mass. Any other installation will give an incorrect engagement result.

B-3. TWGSS FIRING SYSTEM (Con't).

(b) Force-on-force. During force-on-force, the system uses the same size template to evaluate hit or miss for all ammunition types. The template used compensates for the position of turret-mounted retro detector units in relation to the center of mass of the vehicle. This centers the template around the center of mass of a vehicle.

(15) **MILES transmission.**

Note. Refer to detail 8 of Figure 2.

After a completed TWGSS simulation, the transceiver unit transmits MILES information. If the control panel indicates HIT, the transceiver unit transmits MILES to the target that was hit. If a ground hit is indicated, MILES is transmitted at the ground position.

(16) **End of firing simulation.**

Note. Refer to detail 9 of Figure 2.

(a) After a completed simulation cycle, the result is presented to the commander/crew on the control panel. The result presented indicates engagement result (HIT, NEAR MISS, GROUND HIT, etc.), impact point, range to target, and ammunition fired.
(b) This result, together with additional information such as time of round fired, identity of firing system, remaining ammunition, and selected weapon system data, are stored on the TDRS memory card for AAR.
(c) The weapon system data contains information such as selected range in weapon system, turret/hull relation, selected ammunition, fired ammunition, etc.

B-4. TWGSS TARGET SYSTEM.

a. The target computer unit is used to calculate the effects of hits on target (kill probability). The effect of a projectile depends on where it strikes and the type of ammunition being used. The target computer unit determines whether the penetration point falls within the exposed target area of the tank and calculates the effect (probability of kill) of the simulated projectile on the target.

b. A complete target system simulation cycle is illustrated in Figure 13 and described as follows.

(1) **Information reception.**

Note. Refer to detail 1 of Figure 13.

B-4. TWGSS TARGET SYSTEM (Con't).

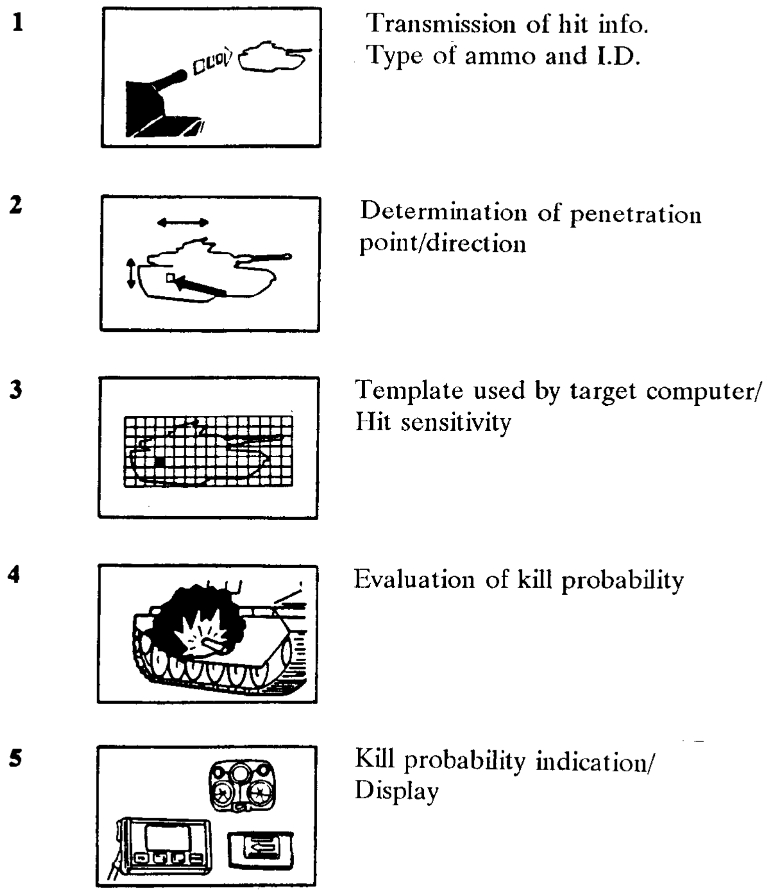

Figure 13

(a) Hit point information sent by the transceiver unit of the firing tank, is received by laser detectors in the retro detector units mounted on the target tank's turret (see Figure 14). The retro detector units are mounted in fixed directions around the tank, providing 360° coverage. The target computer unit is connected to all retro detector units and hull defilade detector units.

(b) The target system determines which detector has received information by determining the direction of the incoming laser light. When information is received by the retro detector units, this information is provided to the target computer unit which performs all calculations.

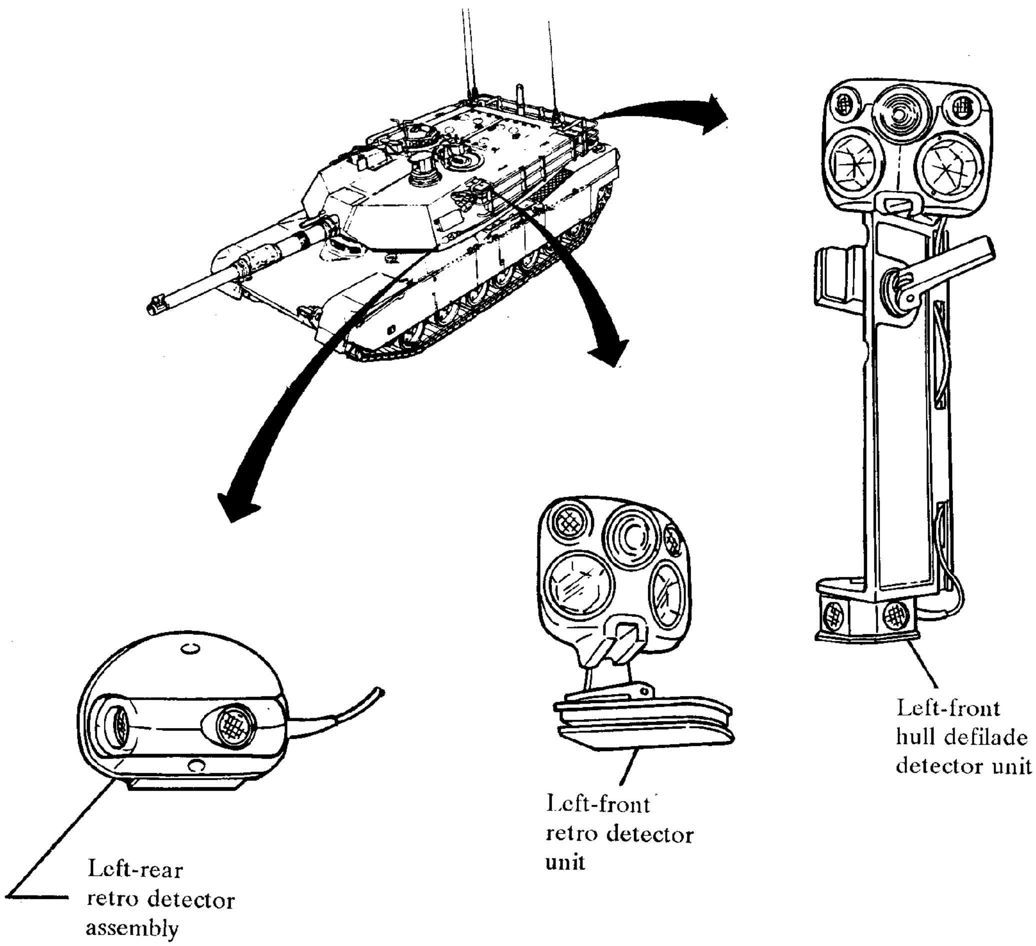

Figure 14.

(c) Before the flying volume, and thus the simulated projectile, reaches the target tank, the firing system of the firing tank sends out information that does <u>not</u> contain hit point data (see Figure 15). This information is ignored by the target computer unit of the target tank. Nothing is stored as results until an actual hit point is determined. When an actual hit point is determined, this information is stored for evaluation using the TDRS computer unit.

(2) **Penetration point and penetration direction.**

B-4. TWGSS TARGET SYSTEM (Con't).

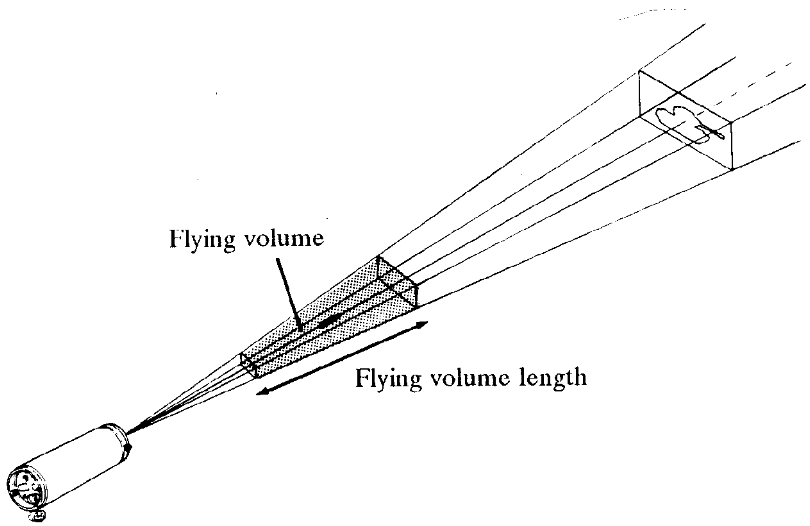

Figure 15.

Note. Refer to detail 2 of Figure 13.

(a) Hit point information, transmitted to the target as a value in relation of the retro detector unit, is re-calculated by the target computer unit to represent an azimuth and elevation distance in relation of the center of mass of the target tank.

(b) The target can be hit simultaneously by simulated projectiles from more than one firing tank. If this happens, the target computer unit evaluates each impact separately. No accumulative effects are calculated if the same area is hit several times.

(c) The impact direction is determined by evaluating which of the detectors received the hit point information. Eight detectors, two in each retro detector unit, are used to calculate 12 30° sectors. Each sector is programmed to represent the target size and vulnerability.

(d) If the penetration point is determined to be above the turret/hull rotation point, the direction indicated by the retro detector units is used. If the hit is determined to be below the rotation point, the direction is determined by the hull defilade detector units. If the hit is determined to be below the rotation point (hull) and the hull defilade detector units DO NOT detect any laser light, the hit is determined to be in the berm of a tank in defilade position (see Figure 16). This tank is not killed and can continue to fight.

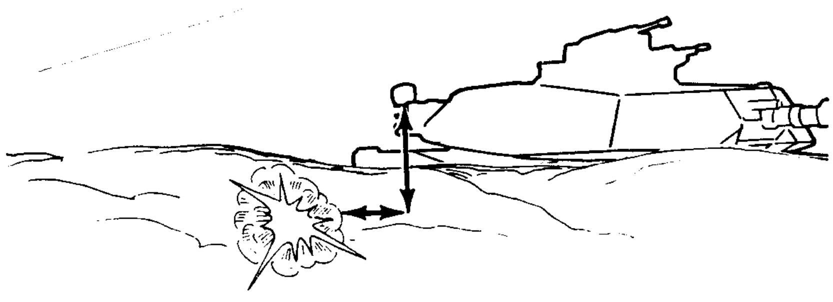

Figure 16.

(3) **Template used by target computer unit.**

Note. Refer to detail 3 of Figure 13.

(a) The target computer unit uses a template in which the contour of the target is viewed from a particular direction. There are 12 templates, one for each of the 12 impact direction sectors.

(b) The templates consist of a grid made up of small squares. Each of these squares provides information of the probability of kill of the target for each type of ammunition used. This information is used to calculate the kill probability of each round impact.

(4) **Kill probability.**

Note. Refer to detail 4 of Figure 13.

(a) The effect (kill probability) of a round on the target is calculated from information about the type of round fired and the impact area's probability of kill. The information sent to the target computer unit includes the type of ammunition used. Other needed information is retrieved from data that was downloaded into the target computer unit from the TDRS memory card at TWGSS power up.

(b) The probability of kill calculation provides the following results:

1. NEAR MISS
2. HIT (no kill)
3. WEAPON KILL
4. MOBILITY KILL
5. KILL

(c) The impact point can lie outside the target outline. In such cases, the target registers NEAR MISS. If the impact point is inside the target outline, the result is HIT. If the hit is determined to be in the tracks or where weapon system components are located, this is indicated on the control panel.

(d) Once a hit is determined, a random number between 1% and 100% is generated. If this number is higher than the probability of kill determined for the impact point, the target tank is killed. If the random number is lower than the probability of kill for the impact point, the target tank indicates HIT, WEAPON KILL, or MOBILITY KILL.

(e) The purpose of the random number is to make the simulation more realistic since a highly effective hit will usually, but not always, destroy a tank. Similarly, an ineffective hit will sometimes destroy a tank.

(5) **Target system indication.**

Note. Refer to detail 5 of Figure 13.

(a) NEAR MISS is indicated by two flashes from the retro detector unit strobe light.

(b) A hit that does not kill is indicated by four to six strobe light flashes.

(c) A hit which kills a tank is indicated by continuous strobe light flashes. A killed tank cannot resume fighting until the system has been reset by an instructor using the control gun.

(d) If MOBILITY KILL is presented on the control panel, the crew must stop the tank within 30 seconds or catastrophic KILL will be indicated.

(6) **End of target system simulation.**

Note. Refer to detail 5 of Figure 13.

(a) After a completed simulation cycle, the result is presented to the commander/crew on the control panel. The result indicates kill probability (NEAR MISS, HIT, MOBILITY/WEAPON KILL, and KILL), impact angle, and impact point.

(b) This target result indication, together with additional information such as time of impact and identity of attacker, are stored on the TDRS memory card for AAR.

(c) Weapon system data such as selected range in weapon system, turret/hull relation, selected ammunition, fired ammunition, etc. is also stored on the TDRS memory card for AAR.

B-4. TWGSS TARGET SYSTEM (Con't).

(7) **Target simulation.**

If the firing system is MILES-equipped only, the evaluation is performed in a similar manner. TWGSS receives information from the attacking MILES and determines direction and effect of the MILES firing simulation. The result of the attack is stored in the TDRS memory card.

Notes:
1. MILES does not send impact point information (i.e., impact point information is not stored with the results on the TDRS memory card).
2. MILES codes received are IAW the enhanced MILES code structure.